THE

INDIAN TEA ASSOCIATION

SCIENTIFIC DEPARTMENT

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PART I

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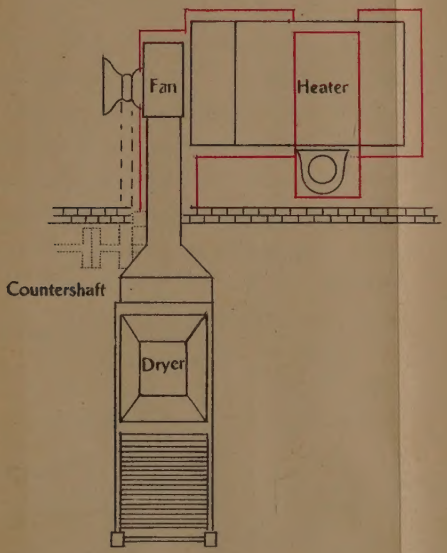
Fig. I.—Sketch showing plan of E. C. P. Dryer w
heater outside building. Cladding is shown by red line



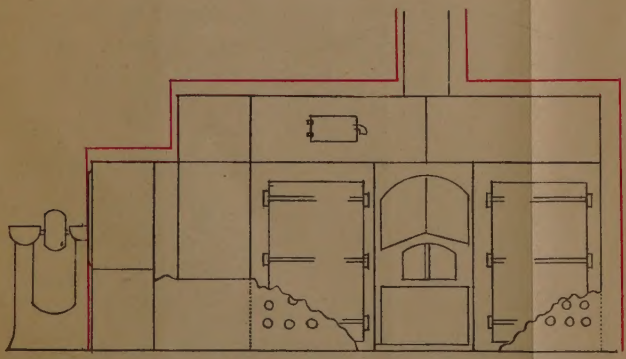
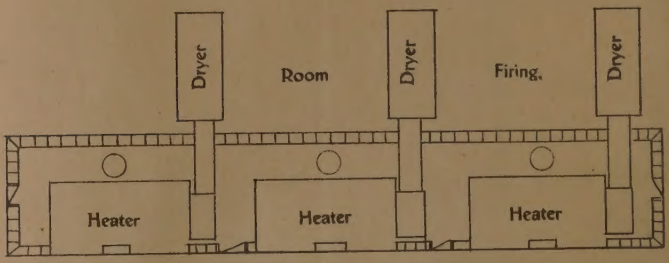


Fig. II.—Front elevation of E. C. P. heater. Cladding is show
by red line.

Fig. III.—Diagram showing the insulation of a range of E. C. P. Dryers by means of a wall.



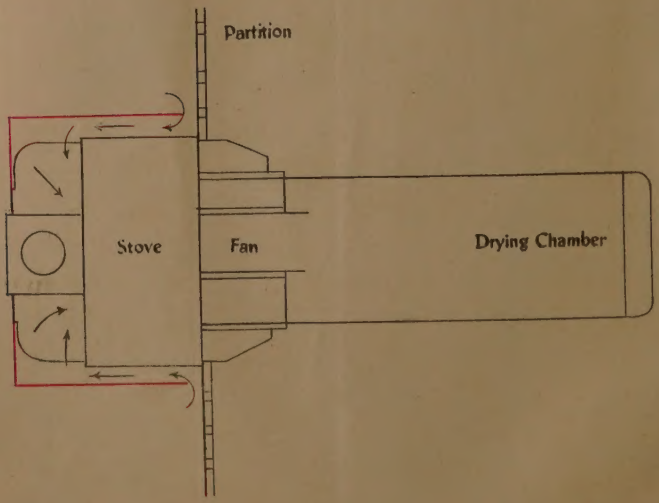


Fig. IV.—Plan view of insulating housing for an Empire Dryer. The cladding is shown by red line.

ECONOMY IN FUEL CONSUMPTION OF TEA DRYERS

BY

C. R. HARLER

Considerable attention has recently been focussed on the question of the efficiency of tea dryers and fuel economy. In most tea factories in North East India the greatest loss in efficiency results from the escape of heat by radiation from the stove of the dryer. A brief note on this aspect of the subject, entitled "The Lagging of Tea Dryers", was published recently in this *Journal* (pt. III, 1930, p. 103), in which methods of insulating the stoves of E.C.P. Dryers were described. Messrs. Marshall, Sons & Co., makers of the Empire Dryers, have since communicated with us describing how the stoves of their dryers can be suitably insulated. On this account the cladding of dryers is now treated afresh and, in addition, various other ways of economising in fuel are denoted.

The efficiency of tea dryers is lost and fuel wasted in a variety of ways, and the fact that fuel consumption in different factories may vary from much less than a maund of coal per maund of tea fired to considerably more than a maund, indicates that the waste may be enormous. It is true that the degree of wither aimed at on different gardens varies widely, and that this factor influences the amount of fuel needed for firing. But after this has been allowed for, there is still much evident waste.

A common source of fuel waste is incorrect stoking. Again, if tea is fired to more than "12-annas" (1) dry in the first fire, the dryer is being employed uneconomically under normal conditions in North East India, and fuel is wasted. Another source of inefficiency is insufficient ventilation of the firing room. This may

(1) *Note.* In India it is common in conversation to express fractions as parts of a rupee, which contains 16 annas. On this account the expression, "12-annas" dry, has become current amongst tea planters to denote three-quarters dry. A 12-anna fired tea is just crisp and contains from 26 to 30 per cent. moisture.

lead not only to the formation of back pressure in the dryer and a corresponding reduction in the air blast and drying capacity, but it may result in a certain volume of the spent, moist air, finding its way to the stove. This air, having already passed through the dryer, has a reduced drying capacity. The most serious and commonest way in which fuel is wasted results from the loss of heat by radiation from the dryer. These four sources of loss will be considered in turn.

Incorrect stoking.

The furnaces fitted to tea dryers in common use in North East India are made to take wood fuel. They are hence not the best suited to the burning of coal, in that this fuel needs a much greater air draught than wood.

For absolute efficiency in combustion the whole of the fuel must be burnt or oxidised to the most complete extent possible. With coal, consisting mainly of carbon, together with hydrogen, nitrogen, oxygen and other substances, the products of complete combustion will consist largely of carbon dioxide and water. In practice combustion is not complete, and only by a sufficient supply of oxygen or air can completeness be approached. If the grate is heaped with coal so that the inside of the bulk receives insufficient air, combustion is markedly incomplete and an analysis of the fuel gases would show, in such a case, the presence of much carbon monoxide and other substances which make up smoke.

Another way in which efficiency is lost is in burning fuel too rapidly, so that the flue gases show very high temperatures. Working under ideal stoking conditions these temperatures should not be higher than about 400 to 500°F. Such temperatures still entail much loss of energy which is, however, unavoidable. If the fire is very fierce then much of the heat passes through the tubes (or over them according to the type of stove) before the air blast passing over them has been heated, and this heat energy then passes into the flue and is wasted. Flue gas temperatures approaching 1,000°F., have been recorded in some tea factories.

In the absence of detailed observations regarding the composition and temperature of the flue gases from tea dryer stoves, recourse must be made to practical experience for information regarding the most efficient method of stoking. Opinions vary on the subject, but, generally speaking, it is considered best to spread the coal in the grate from 4 to 6 inches thick. The spreading should be even. Coal should be added in small charges and for some seconds after the charge is delivered extra air should be given by means of the grate door ventilator. When Bengal coal is used, the lumps which constitute this fuel necessitate a wide space between the fire bars.

Incorrect stoking may waste as much as a quarter of a maund of coal or even more, per maund of tea dried, and in most tea factories it is possible that attention to this matter will lead to considerable saving. (2)

Too full firing.

Experience has shown that the best tea is made when it is dropped from the first firing machine not less than 12-annas dry. If the tea is less fully dried than this, "stewing" takes place on the upper trays of the dryer and "flat" tea results.

Observation has also shown that, for the best results, the tea when it enters the dryer should be met with a blast of air of about 140°F. This means that the temperature below the top tray should be about 140°F., or 120°F., above it. The temperature above the top tray is liable to vary from spot to spot and a more reliable indication of drying conditions is given by taking the temperature below the top tray.

It has further been observed that the initial temperature of the air blast as it enters the dryer should be 180°F. Such a low temperature should be maintained only provided the other two conditions, *viz.*, a 12-anna fire and 140°F. below the top tray, can be realised. (3)

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(2) We are indebted to Mr. G. P. Farrer, Engineer to the Jorehaut Tea Co., for much information regarding the stoking of dryers.

(3) For a fuller discussion on the subject of tea drying see "The Firing of Tea", *Ind. Tea Assn. Quar. Journ.* Calcutta, 1930 (pt. II, p. 67).

It is possible to fire tea fully in one operation, and this is common practice in Ceylon where the wither is usually a full one, and the leaf when fermented contains about 46% moisture. In Assam, even with what is considered a very full wither, when 100 lbs. leaf are withered to 65 lbs., the leaf contains about 60% moisture.

If, under conditions in North East India, firing is carried out in one operation under ideal temperature conditions at the exhaust and inlet of the machine, then tray speeds must be very slow and the leaf spread very thinly. Experience shows that the result of such working is a smaller output per machine than when the firing is carried out in two operations. When tea is fired in one operation the fuel consumption per maund of tea rises.

For the most economical working, the first firing should be to 12-annas. Drying to less than this degree connotes loss of quality and to more than this degree, waste of fuel. The latter loss is so much less important than loss in quality that it is a preferable to be on the safe side and fire to 13 or 14 annas, rather than to drop the tea in a state which may be short of 12-annas dry.

Insufficient factory ventilation.

In many tea factories the ventilation of the firing room is such that the air discharged from the dryers cannot all escape freely from the roof and windows. One result of such a condition will be back pressure in the dryer and reduced working capacity. Another result will be that the warm, moist air will find its way to other parts of the factory and may even be drawn into the stove to be heated again, and sent to the drying chamber. Such re-heated air has a reduced drying capacity and makes for inefficiency in the drying machine.

A knowledge of the volume of air discharged by tea dryers is necessary in order to deal rationally with ventilation problems.

The table below gives figures concerned with drying machines in common use in North East India.

Dryer.	Fan speed, r.p.m.	Air discharged, cub. ft. per minute.
6 ft. Empire	400	10,000—12,000
4 ft. „	400	7,000— 8,000
10 ft. Venetian	450—550	5,000— 6,500
6 ft. „	500	3,000
Paragon	450	5,000
Large E. C. P.	320	19,000
Small „	370	14,200
Double Tilting Tray	370	14,200
Single Tilting Tray	370	8,000

These figures refer to machines running with the air valve fully open. When dryers are run with the air valve partly open, the air discharge is reduced almost in proportion. Thus, with the air valve three-quarters open, the air discharge is about three-quarters that denoted in the table.

With increase in fan speed the volume of air discharged varies directly, within limits. For example, with an Empire Dryer the volume of air discharged with a fan speed of 500 r.p.m. is 1¼ times the volume with a fan speed of 400. With higher speeds this relationship is not maintained owing to air slip. (4)

When the question of room ventilation arises the volume of air emitted by the dryers must be considered. The problem with which a Manager is often confronted may be illustrated by describing a hypothetical case. Thus, suppose that the dryers in a factory consist of two 6 ft. Empires and two 10 ft. Venetians.

(4) *Note.* The three rules for air movement in any particular system are as follows :—

1. The volume per minute varies directly as the fan speed.

2. The velocity head, resistance head and total fan head each vary as the square of the fan speed.

3. The power taken varies as the cube of the fan speed.

Experience in tea factories has shown that the amount of tea dried varies approximately as the square of the fan speed. Thus with a fan speed of 400 r.p.m., the output is to that at 450 r.p.m., as 8 squared is to 9 squared or 64 to 81. The capacity is thus increased about 25 per cent. These valves only hold within limits.

With all four machines working at once, with scheduled fan speeds the air valves fully open, the total discharge of air per minute will amount to about 33,500 cubic feet. Suppose the ventilation consists of a space of 1 foot between the roof and each side of the ridging, extending over a length of 100 feet. The total ventilation area is then 200 sq. feet.

In order that the air discharged from the dryers should all pass through this area, a speed of $33,500/200 = 168$ feet per minute would be necessary. It will be noticed that the cubic capacity of air discharged is divided by the area of the ventilation. Anemometer readings taken by the ridging will denote the air speed and, probably, show it to be much less than 168 feet, since this is a very high rate, denoting that all the air is not leaving by the roof.

If there are windows in the roof or clearstory (*i.e.*, the wall from the main to the verandah roof) these must be considered in calculating the ventilation area.

If the air does not all escape freely through the roof and roof windows, some will find its way to other parts of the factory and the question which arises is, does any re-enter the dryer tubes. It is possible to settle this question by means of wet and dry bulb thermometer readings, although we have as yet no experience in this matter to pass on to the planter. The following discussion, however, will illustrate the method of approach to the problem.

The air to feed the dryer tubes should be drawn from outside the factory. If this air alone is being used, then the amount of moisture per cubic foot in the air just near the tubes should be the same as that in the air just outside the factory. Suppose the outside air shows dry and wet readings of 90°F. and 80°F., respectively. Reference to hygrometrical tables (5) will show that such air contains 8.7 grains water vapour per cubic foot. When the wet and dry bulb thermometers are placed near the dryer tubes, higher temperatures will be observed, on account of the proximity

(5) Hygrometrical Tables supplied by Messrs. Mather and Platt, Calcutta, give sufficient figures for tea factories.

to the stove. Thus, suppose readings of 100° and 84°F., for the dry and wet bulbs are observed in this case. Further reference to the tables shows that such air contains 8.9 grains water vapour per cubic foot, which is practically the same as in the outside air. The conclusion in this case is that no exhaust air is returning to the stove tubes.

The damp, warm air which issues from the dryer shows dry and wet readings of about 120°F. and 100°F., respectively. Such air contains about 13.5 grains water vapour per cubic foot.

It will be seen that any considerable movement of this discharged air towards the dryer tubes will raise the moisture content of the air taken into the dryer. As mentioned above, we are not able, yet, to give typical readings in well and badly ventilated firing rooms. If a movement of damp exhaust air towards the stove is detected, the latter should be partitioned off from the drying chamber by a wall or otherwise. The accompanying sketches, *Figs. I, III* and *IV*, indicate how stoves may be cut off from the possible inflow of discharge air from the dryer itself. The walls shown in *Fig. III* also act as an insulator to the dryer.

Insulation of the stove.

As previously noted, the question of the insulation of tea dryers was discussed in an earlier number of our *Journal*. The three sketches used in that article are reproduced here, together with a fourth (*Fig. IV*) which shows insulating housing for the Empire type of stove. The housing is made of light angle iron and the walls and roof are filled with ¼″ asbestos sheeting or thin gauge sheet iron. A space of about 9″ to 12″ is left between the housing and the top and sides of the stove and the air is drawn in through this at the end nearest the drying chamber. By passing over the stove and near the chimney before entering the tubes, the air is pre-heated with a resultant saving on fuel.

In the housing, provision should be made for doors in the sides and front so that there is no difficulty in getting at the stove tubes for cleaning purposes.

It is considered advisable to construct a partition, as indicated in the diagram (*Fig. IV*), between the stove and the drying chamber to prevent any possibility of moist exhaust air from the drying chamber being drawn back through the stove. At the same time care should be taken to allow ample space between the wall and the housing to let the air pass freely to the stove, and any risk of restriction of air movement should be avoided. (6)

With the E. C. P. type of stove the cladding is so arranged that the air enters at the top of the heater and is drawn right round the stove and across the tubes, an arrangement which gives considerable pre-heating. In order not to starve the machine of air, caution must be taken to ensure that the air inlet space above the stove is at least equal in area to the sum of the areas of the two ordinary side inlets and the inlet by the chimney of the stove.

Both Empire and E.C.P. stoves are meant to be lagged, although this is seldom done in North East India. On this account the saving in fuel made possible by insulating unlagged machines at first seems incredible. Thus in some cases fuel economy up to 42% has been realised on insulating an unlagged machine, situated in a cool draught. Normally a saving in fuel of 25% may be anticipated by insulating unlagged drying machines.

The probable total saving to the Industry derived from the insulation of dryers may be calculated. Assuming that the annual tea crop in North East India is about 320 million pounds, and that one maund of coal costing one rupee is used for drying one maund of tea, a saving of 25% in fuel would indicate an annual saving of 10 lakhs of rupees.

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(6) We are indebted to Messrs. Marshall, Sons & Co., Ltd., for much data in connection with firing machinery.

THE CHEMISTRY AND PHARMACOLOGY OF A CUP OF TEA

BY

P. H. CARPENTER AND C. R. HARLER

A number of articles describing the chemistry and pharmacology of tea have been published. In some cases, far reaching conclusions have been drawn on scanty evidence, whilst in others, attempts to advertise certain teas or to introduce other beverages at the expense of tea have resulted in the expression of biassed opinion.

The writers of the present article are engaged in research on tea in North East India and are thus open to the charge of prejudice in favour of India teas. On this account all our statements are, wherever possible, supported by scientific evidence or, where this is lacking, are based on general scientific principles.

Most articles dealing with the value of tea as a beverage concentrate on the action of tea tannin in the alimentary tract, and it frequently happens that very wrong conclusions are drawn in this respect. Accordingly, the main part of this paper deals with the chemistry and pharmacology of tea tannin.

The Manufacture of Tea

Tea is made from the young shoots of a shrub, *Thea sinensis*, which has been found growing wild in Assam, Burma and parts of southeast Asia. There are two main varieties of the tea plant, *viz*, the China or small leaved and the Assam or large leaved variety. The China plant is cultivated in China, Japan, Formosa and the hill districts of India and Ceylon. The Assam plant is grown in the plains of North East India, South India, Ceylon, Java and Sumatra.

Tea leaf is manufactured into green or black tea. Most of the green tea is made in China and Japan, whilst black tea is made in India, Ceylon, Java and China. Only small quantities of green tea are made in India. Green tea is mostly drunk

in China and Japan and to some extent in America. Its liquors are light in colour and body. Black tea is drunk in Great Britain and the Dominions. Its liquors are red in colour and are stronger and thicker than those of green tea.

The manufacture of green tea is comparatively simple. The leaf when it is plucked is brought to the factory and either steamed or placed in a hot pan and stirred for a few minutes. The result of such action is to kill the leaf, which is then rolled and dried. The preliminary heating of the fresh leaf stops chemical action during the rolling process, with the result that the fresh leaf and green tea are practically identical in composition.

When black tea is made, the plucked leaf is first allowed to wilt or wither, after which it is rolled and "fermented". The rolling process expresses and mixes the juice of the leaf and exposes it to the air. In Chinese tea gardens the withering process is a short one. The leaf is rolled by hand several times, with short periods for "fermentation" between the rolling. When the right aroma is developed further chemical action is stopped by heating the leaf in a pan. More rolling takes place before the leaf is finally dried over a small fire.

In the tea estates of India, Ceylon and Java, which are largely European controlled, the leaf is allowed to wither for about 18 hours after which it is rolled by machinery. The rolled leaf is then spread in a thin layer and placed in a cool room to oxidise or ferment. When the process has gone far enough the leaf is placed in an automatic firing machine which, by a blast of hot air, stops further chemical action and dries the tea.

The Oolong teas of Formosa and parts of China are semi-fermented. After a short wither the leaves are lightly rolled and bruised and the incipient fermentation thus set up allowed to proceed for an hour or so, after which the leaf is heated to about 160°F., and further chemical action stayed. The leaf is then given additional rolling and is finally fired.

The composition of tea leaf and tea.

The frame of the leaf is made up of cellulose and fibre, which with pure proteins and starch compose much of the water-insoluble matter in the leaf. Tea tannin, caffeine, protein bodies, gummy matter and sugars are other important constituents which, unlike the foregoing, are soluble in water. In addition, tea contains small quantities of mineral substances, chlorophyll pigments, waxes and resins, mucilages and pectic bodies and oxalic acid, *etc.*, which are more or less soluble. All these bodies are present in both black and green teas.

Black tea contains, in addition to the above substances, oxidised tannin products and traces of what is often spoken of as the tea essential oil. (1) Green tea is devoid of these substances.

The approximate constitution of fresh leaf and green tea made from that leaf is the same. In black tea manufacture, however, considerable chemical changes take place. These changes are illustrated by the following analysis, made in Assam, the values shown being typical for India teas. Percentages in this and subsequent tables are calculated on dry matter. The soluble matter was obtained by boiling with water for one hour.

The composition of fresh tea leaf and black tea made therefrom

		Fresh leaf	Black tea
Cellulose	insoluble in water	12%	12%
Crude fibre		21%	21%
Pure proteins		17%	16%
Starch		0·4%	0·2%
Tea tannin	soluble in water	22%	12%
Caffeine		4%	4%
Gummy matter		3%	2%
Sugars		1·0%	1·5%
Soluble minerals (ash)		4%	4%
Protein bodies		12%	13%
Oxidised tannin products		*nil.*	2%
Chlorophyll pigments		1·5%	1·0%
Total ash		5·5%	5·5%
Tea essential oil		*nil.*	traces.

It will be seen that the main change taking place during black tea manufacture is the disappearance of tea tannin which,

(1) H. Finnemore, *The Essential Oils*, London, 1926 (p. 509).

in the experiment detailed above, fell from 22 to 12%. Some of this tannin reappears as a red, oxidised tannin body which is soluble in a tea infusion, but most is apparently fixed, insoluble, within the leaf.

There is a limited change of pure proteins in manufacture which break down to soluble protein bodies. Slight starch decomposition also takes place and a small increase in sugars. The chlorophyll is partly decomposed, mainly during the firing process.

The table given above merely indicates the nature of the changes taking place, and the figures cannot by any means be taken as an average for black teas. Thus, for example, as grown in China, the China variety of tea bush gives leaf containing about 15% tannin and China black tea contains only about 7 to 10% tannin. Darjeeling and high-grown Ceylon teas which are made from bushes of the China variety generally contain less tannin than Assam teas. The China bush when grown in the plains of Assam, Ceylon and Java gives leaf containing about the same tannin percentage as the leaves of Assam bushes. The changes undergone by this leaf during manufacture are comparable to those shown in the table above.

In the table above the soluble constituents in black tea extracted by prolonged boiling are shown. If tea is infused for 5 minutes, much less is extracted. The table below compares the total water-soluble matter in black tea with that extracted by a 5-minute infusion.

Water-soluble matter in tea and in a tea infusion

	Total soluble matter on boiling 1 hour	Matter soluble in 5-minute infusion
Tea tannin	12·0%	7·0%
Caffeine	4·0%	3·0%
Protein bodies	12·0%	6·0%
Gummy matter	2·0%	1·0%
Sugars	1·5%	1·0%
Soluble minerals (ash)	4·0%	2·5%
Oxidised tannin products	2·0%	2·0%
Total soluble solids	37·5%	23·0%

Estimations of the soluble constituents of tea may show wide variations. The next table (2) shows the solids extracted by 5-minute infusions from teas from various sources. The first four sets of figures were obtained by a worker in Java and represent extreme limits of values. The observations on India teas were made in Assam and show normal limits of variation.

Table showing caffeine, tannin and soluble solids extracted by a 5-minute infusion

	Caffeine	Tannin	Soluble solids
Java black teas ...	2·7 to 4·4%	6 to 20%	16 to 26%
Japan green teas ...	2·0 to 3·3%	4 to 12%	16 to 26%
China black teas ...	2·0 to 3·7%	5 to 10%	16 to 22%
Formosa Oolong teas ..	3·1 to 3·7%	12 to 23%	23 to 25%
India black teas ...	2·0 to 3·0%	6 to 10%	22 to 25%

The values given by Deuss in the above table resulted from analysis made with a view to correlating the caffeine, tannin and water-soluble solids in a tea infusion with the quality and market value of the tea as denoted by a tea taster. The conclusion arrived at was that no such correlation exists. Carpenter and Cooper (3) have reached the same conclusion regarding India teas.

It is now of interest to discuss the reasons why tea is used as a beverage. It is probable that an infusion of dried tea leaf was originally drunk on account of the stimulant, caffeine, it contained, although there is no apparent correlation between the market value of tea, as sold nowadays, and its caffeine content.

The most highly valued teas are priced on their flavour and aroma. All black teas contain a minute quantity of what is generally called the tea essential oil, but certain district and seasonal teas have distinctive flavours of high market value. The black tea essential oil consists mainly of β—γ—hexenol with a trace

(2) J. J. B. Deuss, "L'analyse chimique du thé en rapport avec sa qualite", *L'Agronomie Coloniale*, Paris, 1924, No. 80.

(3) P. H. Carpenter and H. R. Cooper, *Ind. Tea Assn. Quar. Jour.* Calcutta, 1932 (pt. 2).

of methyl salicylate. (4) Distinctive tea flavours are due to substances in addition to these.

The tannin in a cup of tea gives it its astringent quality. Inveterate tea drinkers, like the British and Australians, have acquired a taste for tea tannin and prefer strong teas on this account.

The soluble protein bodies in tea are present in too small quantity to be of any appreciable value in a normal diet. The calorific value of the soluble carbohydrates in tea are similarly so small as to be of little dietetic importance. The protein bodies and carbohydrates together with tannin and caffeine go to make the "thickness" of the tea infusion.

It has been claimed that certain green teas are rich in vitamin-C. The general conclusion is, however, that the vitamin content of any tea is not great enough to be of importance in the diet of the average person.

It is now proposed to consider the two most important constituents of a tea infusion, caffeine and tannin, in some detail.

Caffeine

Caffeine is an alkaloid, first discovered in coffee in 1830. It was discovered in tea in 1827 and named theine, and was later found in maté and other plants. Eventually theine was shown to be identical with caffeine and the term theine then ceased to be used by chemists. Caffeine has been synthesised and its constitution and chemistry are fully known.

Caffeine is used as a drug and its action on the human system is stated by the *British Pharmaceutical Codex* (5) to be as follows :—

> Caffeine exerts three important actions, (*a*) on the central nervous system, (*b*) on muscles, including cardiac, and (*c*) on the kidney.

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(4) P. van Romburgh, *Schimmel's Berichte*, Leipzig, Ap. 1897, 39; Ap. 1898, 50; October 1920, 65.

(5) *British Pharmaceutical Codex*, Ed. 1923 (p. 228).

The action on the central nervous system is mainly on that of the brain, connected with physical functions. It produces a condition of wakefulness and increased mental activity. The interpretation of sensory impressions is more perfect and correct, and thought becomes clearer and quicker.

With larger doses of caffeine the action extends from the physical areas to the motor area and to the cord, and the patient become at first restless and noisy, and, later may show convulsive movements. Caffeine facilitates the performance of all kinds of physical work, and actually increases the total work which can be obtained from a muscle. In the normal man, however, it is impossible to say how much of the action in the muscle is central and how much peripheral. But, as fatigue shows itself first by an action on the centre, it is probable that the action of caffeine in diminishing fatigue, is mainly central. Caffeine accelerates the pulse and slightly raises the blood pressure. It has no action in any way resembling digitalis. By increasing the irritability of the cardiac muscle, its prolonged use rather tends to fatigue than to rest the heart.

Caffeine and its allies form a very important group of diuretics. The urine is generally of a lower specific gravity than normal, since it contains a lower proportion of salt and urea; but the total excretion of solids both as regards urea, uric acid and salts, is increased. Caffeine, by exciting the medula, produces an initial vasco-constriction of the kidneys, which tends at first, to retard the flow of urine.

The medical dose of caffeine is 1 to 5 grains (6 to 30 centigrams).

This account represents considered British medical opinion and only contains such facts as are thought sufficiently established for publication.

The average caffeine dose suggested by the Pharmacopœia of the United States is 2½ grains (15 centigrams).

India tea contains about 4% caffeine. The annual tea consumption in Great Britain is about 9 lbs. *per capita*. This quantity of tea contains about 2,520 grains of caffeine. Assuming that about three-quarters of the caffeine is extracted when tea is brewed, the average annual consumption of caffeine would be about 1,890 grains (about 4 ounces). The average daily consumption is thus about 5 grains.

A pound of good tea makes about 200 cups of the beverage. Since this quantity of tea contains about 280 grains of caffeine, each cup of tea made from freshly infused leaf contains about one grain of the stimulant.

Many experiments have been made on animals and humans in the study of the effect of caffeine on heart action, blood pressure, muscular activity and so on. The most complete study of the subject was carried out by Hollingworth (6) who made an enormous number of observations. The experiments were conducted in a specially equipped laboratory and the subjects treated with caffeine for a period of 40 days under controlled conditions. For details of the experimental technique the reader is referred to a monograph in the Archives of Psychology of Colombia University, New York, entitled "Colombia's Contribution to Philosophy and Psychology".

The caffeine was given in capsules and in syrup, the dose ranging from 1 to 6 grains, above 4 grains being reckoned as a large dose.

The general conclusions arrived at were that the effect of caffeine on motor processes is quickly realised and is transient, whilst that on mental processes comes more slowly but is more

(6) H. L. Hollingworth, "The Influence of Caffeine on mental and motor efficiency", *Ther. Gaz.*, Vol, 28, 1912 (No. 1, p. 1).

persistent. No secondary reaction was observed in any test, even with what was considered a big dose.

It was further observed that the two main factors which seem to modify the influence of caffeine are body weight and presence of food in the stomach. In practically all the tests, the influence of the caffeine varied inversely as the weight of the subject, and was most marked when taken on an empty stomach or without food substance.

The effect of caffeine did not seem to be influenced by age, sex or previous caffeine habits.

The experiments just described were carried out with caffeine in the free state. No definite information regarding the state of caffeine in the tea leaf or in tea can be given. It has been wrongly supposed (7) that in a tea infusion the caffeine is combined with tea tannin. Deuss (8) has prepared caffeine-tea-tannate in the absence of water, and has observed that this compound is decomposed by water.

A discussion on the supposed compound of tea tannin and caffeine is given in a later section.

Tea tannin

In discussing the action of tea in the alimentary tract it is common for critics of the beverage to refer to "tannin" as though it were a single substance, instead of a large group of widely differing substances. On this account it is proposed first of all to give a brief account of natural tannins in general. Many synthetic tannins, of a comparatively simple nature, have been prepared.

Some years ago, before the study of the tannin group had advanced far, the term "tannin" was often employed to denote the tannin of oak galls. Present day chemists use the term

(7) Anonymous, "The Chemistry, Physiology and Aesthetics of a Cup of Tea", *The Lancet*, London, January 7, 1911.

(8) H. Neuvile, *Technologie du Thé* Paris, 1926 (p. 19).

as a generic one to denote a large body of substances which have certain properties in common.

Tannins are vegetable substances occurring in the higher plants. They are found in the bark of some plants, in the wood, leaf or pods of others. The extraction of tannins for use in tanning hides is an important industry.

The chief properties of tannins may be summarised as follows :—

1. They are mostly uncrystallisable, colloidal substances, soluble in water, slightly acidic and showing astringent properties.
2. They form blackish-blue or blackish-green compounds with iron salts, these compounds having been originally used as inks.
3. They precipitate gelatine from solution and form insoluble compounds with gelatine-yielding tissues, a property which enables them to convert hide into leather.
4. They precipitate alkaloids and substances of a basic nature.
5. In alkaline solution the tannins and many of their derivatives readily absorb oxygen, becoming dark in colour.
6. In acid solution the catechol tannins produce insoluble red substances known as phlobaphenes or "reds".

Tea tannin exhibits these properties except the third, and, since it has no tanning power, is classed as a pseudo-tannin.

The chemical nature of tannins differ widely, according to their source. The extensive study of their reactions has furnished a basis for several schemes of classification. The tannins fall into two general classes which have been named *pyrogallol*

and *catechol* from the fact that on dry distillation tannin materials give one or the other of these substances.

One well-known scheme of classification is that of Proctor (9) who divided the natural tannins as follows :—

1. Pyrogallol tannins, including divi-divi, galls, sumach, myrobolans, oak galls and wood, and chestnut tannins.

2. Catechol tannins, including all the pine, acacia, mimosa and oak barks (but not oak wood or galls), quebracho wood, cassia, canaigre cutch and gambier.

Each group has distinctive properties. The tannin used in pharmacopœia, usually called *acidum tannicum*, is a pyrogallol tannin, whilst tea tannin belongs to the catechol group.

In 1918, Perkin and Everest (10) suggested a new classification, more discriminating than the others in that it took into consideration the structure of the tannin molecule and was not based mainly on the properties of the tannins.

In 1920 Freudenberg (11) offered a still more distinctive classification, one made possible by the great advances in tannin research during recent years. The outstanding feature of chemical investigation in this sphere was the synthesis of gallotannic acid by Emil Fischer in 1918, (12) which profoundly modified previous views on the subject of tannin chemistry. Freudenberg, formerly associated with Fischer, is carrying on that great master's work, and both he and Nierenstein have done much towards determining the constitution of catechin, which stands, with regard to the catechol tannins, somewhat as gallotannic acid does to pyrogallol tannins.

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(9) H. R. Proctor, *The Principles of Leather Manufacture*. London, 1903.

(10) A. C. Perkin and A. E. Everest, *The Natural Organic Colouring Matters*, New York, 1918.

(11) K. Freudenberg, *The Chemistry of the Natural Tannins*, Berlin, 1920.

(12) E. Fischer, *Ber. deut. chem. Gesell.* Berlin, 1918 (51, p. 1760) and 1919 (52 p. 829).

Freudenberg divided the tannins into two main classes :—

1. Hydrolysable tannins, in which the benzene nuclei are united to larger complexes through oxygen atoms.

2. Condensed tannin, in which the nuclei are held together through a carbon linkage.

Group 1 embraces (*a*) esters of phenolcarboxylic acids with each other or with oxyacids (depsides), (*b*) esters of phenolcarboxylic acids with polyatomic alcohols and sugar (tannin class) and (*c*) glucosides. The most important criterion for group 1 is hydrolysis to simple components by enzymes, particularly tannase (secreted by *Aspergillus niger*) or emulsin.

Tannins of group 2 are not decomposed to simple components by enzymes. They generally are, but not always, precipitated by bromine and, when treated with oxidising agents or strong acids, condense to high molecular tannins or "reds". They are divided into two classes according to whether or not phloroglucin is present. With some exceptions, the catechins belong to the phloroglucin class, *e.g.*, querbracho, and probably oak tannin are in this class.

The ordinary tannin of pharmacy belongs to group 1 of Feudenberg's classification. Tea tannin is classed in group 2, but the presence or otherwise of phloroglucin has not yet been shown.

The foregoing will suffice to indicate the wide range in properties of tannins from different sources.

The tannin of pharmacy, digallic acid or *acidum tannicum*, is obtained by fermenting gallotannic acid, the tannin from oak galls. This natural tannin, penta-digalloyl-glucose, thus gives digallic acid, a simple tannin whose constitution and properties are well known.

The following extract from the *British Pharmaceutical Codex* (13) is taken from the account given under the heading "Acidum Tannicum or Tannin".

> The properties of tannin depend upon its chemical interaction with protein or gelatine..... The free acid only is astringent and when it is neutralised by albumin or alkalies its astringent properties are lost.
>
> When taken by the mouth it gives the characteristic property of astringency, coagulates the protein material surrounding the epithelium and even penetrates some of the superficial cells.
>
> In the stomach it combines with alkalies and albumin to form tannates. Albumin is digested like other coagulated proteins, the tannin being again liberated to recombine. The tendency in the intestine, by coagulating proteins and diminishing secretions, tends towards constipation. It is therefore used occasionally in diarrhœa.
>
> The proper dose is 5 to 10 grains (3 to 6 decigrams).

The dose suggested in the United States Pharmacopœia is 8 grains.

Other tannins used in medicine are myrobolans, catechu and black catechu. Myrobolans is obtained from the immature fruits of the tree Terminalia Chebula, *Retz.* In small doses it acts as an astringent, reducing the secretion in the intestine and thus having a use in staying diarrhœa. In large doses, 30 to 60 grains, it activates the secretion of the liver and in this manner acts as a purgative.

Catechu is obtained from the tree Uncaria Gambia, *Roxb.*, and Black catechu from Acacia catechu, *Willd.* Both are given in doses of 5 to 15 grains and act as astringents.

(13) *British Pharmaceutical Codex*, Ed. 1923 (p. 51).

One point in the chemical action of digallic acid as outlined in the *British Pharmaceutical Codex* is open to objection. Thus, tannin will not combine with alkalies in the stomach, where the medium is strongly acid. Again, in the intestine, where the medium is alkaline, tannin will only coagulate proteins if the alkalinity is first overcome. This may happen, but it is not probable that any acid reaction from *acidum tannicum* would be other than very local. This is, in practice, generally realised to be the case. (14)

Most of the criticism of tea as a beverage is based on the assumption that tea tannin has the same action as *acidum tannicum* in the alimentary canal. It is now proposed to discuss the properties of these two substances, and to show that they differ considerably.

Acidum tannicum or digallic acid is a pyrogallol tannin. It is synthesised by condensing two molecules of gallic acid, and has the formula $C_{14}H_{10}O_9$ or $C_{14}H_4O_2$ $(OH)_5$ COOH. Tea tannin is a catechol tannin whose formula is not fully worked out, but has been given as $C_{20}H_{20}O_9$ or $C_{20}H_{12}O$ $(OH)_8$ by Deuss, studying tea tannin in Java, (15) and as $C_{22}H_{18}O_9$ or $C_{22}H_{11}O_2$ $(OH)_7$ by M. Tsujimura working in Japan. (16) The latter worker has given a much more detailed structural formula than Deuss. The empirical formulae given by both workers are similar.

Digallic acid contains a carboxyl group and is a moderately strong acid with a pH value of 3. Tea tannin contains no carboxyl ground and is a much weaker acid with a pH = 4.4. The oxidised, red tea tannin which appears in a tea infusion shows the same acidity as the unchanged tea tannin. *Acidum tannicum* is thus about 25 times stronger as an acid than tea tannin. All these acidities are weak, however, compared with that of the stomach juices which show a pH value of about 1.5.

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(14) E. Whitta, *Elements of Pharmacy, Materia medica and Theraputica*, London, 1915 (p. 313).

(15) J. J. B. Deuss, *Med. Proef. Stat. Thee*, Buitenzorg, 1913, No. 13.

(16) M. Tsujimura, *Bull. Agr. Chem. Soc. Japan*, 6, 70-5 (1930), 7, 23-8 (1931).

Chemically tea tannin is very different from *acidum tannicum*. The most important difference is the fact that tea tannin is not a true tan, but a pseudo-tan. True tannins have tanning properties well developed and are able to precipitate gelatine from solution. Tea tannin gives only a cloudiness with gelatine and only precipitates in a strong acid solution.

Tea tannin is fixed by an insoluble, complex protein body like hide powder, but it has no power to precipitate caseinogen from fresh milk.

Tea tannin in the unoxidised state, as it occurs in the fresh leaf, does not precipitate the leaf proteins. Thus if tea leaf be crushed *in vacuo* so that the tannin and proteins in the cell sap are mixed, no combination takes place.

Tea tannin, in common with other tannins, can be oxidised with the formation of red or brown products. Some of these products are true tannins, whilst others are insoluble bodies, known as phlobaphenes which, of course, have no tanning powers. A study of some of the changes undergone by tea tannin is instructive.

When tea leaf is rolled or crushed in air, as in the manufacture of black tea, oxygen is rapidly absorbed. This is due to the fact that the enzymes in the leaf are assisting in the oxidation of the tea tannin to red and reddish brown products. It is probable that, in addition to oxidation, the tannin molecule undergoes condensation during black tea manufacture. The tannin products thus formed can be divided into several groups according to their properties.

Some of the tannin products are pseudo-tans and are unable to precipitate gelatine from a water solution. Others are true tans and are able to precipitate the proteins in the leaf juice. On this account some of these products are fixed in the leaf. Other products are soluble in the hot infusion but are precipitated on cooling and standing for an hour or so. These products are referred to as the "cream" by tea tasters.

When a tea infusion is allowed to stand, its tannin value decreases and a precipitate forms. This precipitate increases with time and the tannin left in solution decreases. When the infusion and precipitate are warmed, some of the latter redissolves but all the tannin is not thereby recovered. The exact nature of the tannin changes occurring under these conditions is not yet known. The original tea tannin as it occurs in fresh tea leaf does not show these changes in solution, but is stable. Apparently only after the tea tannin molecule is oxidised or condensed are such changes possible.

Below are tabulated three groups of tannin products, with some of their properties, which appear to be formed in black tea manufacture. For comparison some of the properties of unchanged tea tannin are given.

1. Original tea tannin—White, amorphous powder, soluble in water to give a colourless solution; a pseudo-tan.

2. First group of tannin products—Red, amorphous powder, soluble in water to give a red solution; pseudo-tans.

3. Second group of tannin products—Dark red, amorphous powder, soluble in water to give a red solution; able to precipitate proteins. These bodies are largely fixed by the leaf proteins, after which they do not enter the tea infusion.

4. Third group of tannin products—Dark red, amorphous powder, soluble in hot water, very slightly soluble in cold water. These bodies on precipitation form the "cream" of tea. They have only very slight or no tanning powers.

By oxidation in alkaline solution tea tannin forms phlobaphenes and in a strongly alkaline medium still further oxidation

products result. In an acid medium with the aid of heat, even in the absence of air, other phlobaphenes are formed. It is not known whether these products are formed in black tea as manufactured in India, although their presence or otherwise is not important in this discussion since they have no tanning powers.(17)

During the fermentation process in the manufacture of black tea in India, the tannin content of the leaf falls from about 20% in the fresh leaf to about 10% in the fully fermented leaf or fired tea. The 10% tannin includes any true tans and also pseudo-tans which only precipitate gelatine with the aid of strong acid. The loss of 10% of the tannin in fermentation is partly due to the formation of "cream", but in the main probably due to the fixation of oxidised tea tannin coming under group 3, above, by the leaf proteins. It has not been possible to prove definitely this last point so far, but since the tannin under discussion does not enter the tea infusion, its ultimate fate is not a primary question here.

Of interest, however, is any oxidised tannin with properties allied to true tans, which for some reason is not precipitated in the leaf, but remains free to enter the infusion. It is difficult to get a measure of any such substance, but it is seen that in a black tea infusion some of the tannin is precipitated by gelatine without the aid of strong acid. In an infusion of a strong tea much of the tannin may act in this manner. The table below shows the figures given by a fine grade Broken Orange Pekoe. The active tannin denotes that retained by a gelatine solution, of concentration the same as that used in Loewenthal's method for estimating tannin, (18) on filtering with China clay as an aid. The pseudo-tannin is that not so precipitated.

	5-minute infusion	1-hour extraction
Total tannin	8·6%	15·5%
Pseudo-tannin	2·3%	3·9%
Active tannin	6·3%	11·6%

(17) For a fuller discussion of tea tannin phlobaphenes refer to "The Withering of the Tea Leaf" by C. R. Harler, *Ind. Tea Assn., Quar. Jour.*, Calcutta, 1930 (pt. 4).

(18) Procter's modification of Loewenthal's method, *U. S. Dept. Agr. Dept. Chem.*, Washington (bull. No. 13, pt. 7, p. 80).

Thus about three-quarters of the tannin in a 5-minute infusion may be said to be active. The China clay used to aid filteration was in itself responsible for the precipitation of about a third of the tannin which is denoted as active tannin.

The probable action of the tannin in a tea infusion during its passage through the alimentary tract may now be discussed.

When fresh milk is added to a normal black tea infusion, no precipitation of caseinogen occurs. If milk is just "on the turn" *i.e.*, if it has developed sufficient acidity to bring the caseinogen to the point of coagulation and precipitation, oxidised tea tannin may complete the process. This accounts for the curdling of such milk when added to tea. Tea which is sufficiently milked has any possible tanning and astringent properties allayed.

If tea be drunk without milk, then an astringency or contraction of the membrane is experienced in the gums. The saliva is alkaline and since tannin only shows astringency when in the free state, this alkalinity must be neutralised before the astringent sensation is experienced. On this account a very small quantity of unmilked tea is not astringent, whilst a larger quantity is.

When tea passes from the mouth, through the gullet the active tannin therein is held by the caseinogen in the milk. When the tea reaches the stomach it enters a strong acid medium and even the pseudo-tannin is then fixed by proteins.

It is assumed in the *British Pharmaceutical Codex* that the protein complex attached to the tannin is decomposed by the stomach juices and the tannin liberated. If this is so, the tannin will then recombine with any food proteins or protein bodies it finds present in the stomach. The fixation of some of the food protein in this manner is not a serious matter since a cup of tea only contains about 3 grains tannin which at a very liberal estimate would not fix more than about 10 grains protein. Since the average man requires about 1,300 grains proteins daily and usually consumes much more than this quantity, any small reduc-

tion owing to the presence of tea tannin in the stomach is not serious.

The popular idea of the stomach lining becoming tanned by tea so that it resembles leather is one to be mentioned only to be dismissed as foolish.

When the partially digested food in the stomach has reached a certain state it is passed into the small intestine, whence it in time passes to the large intestine and is eventually excreted.

Throughout both intestines the reaction is alkaline. When the tannin-protein compound enters the intestine, the alkalinity decomposes it, liberating the tannin.

The reaction of the tannin is now influenced by the alkalinity of the intestinal medium. If the acidity of the tannin is strong enough to overcome the alkalinity of the intestine then astringency will assert itself, and combination with protein bodies become possible. With combination, the astringency is lost, so that any action in the small intestine must be very local.

It is possible that the tannin may be oxidised to insoluble phlobaphenes in the intestine. In this case the effect would be the end of its activity, a result similar to that arising from fixation by protein bodies.

To return now to medical practice, it is known that a total daily dose of *acidum tannicum* of 45 grains will completely constipate in 3 days. No definite experiments regarding the action of tea tannin on the human system have been published, and conclusions drawn regarding the influence of tea drinking are made on unfounded assumptions resulting from a lack of knowledge of the nature of tea tannin.

At Cinnamara, in Assam, a direct experiment has been made regarding the influence of tea tannin on the human system. (19)

(19) We are indebted to Dr. D. Manson, Medical Officer to the Jorehaut Tea Company, for carrying out these experiments. The tea tannin was taken by two members of the Cinnamara Hospital staff who during the experiment followed their normal habits.

Tannin was extracted from tea leaf in the pure form and administered as the powder in 3 daily doses each of 15 grains for 3 days, to two adult men. The total dose for the period was thus 135 grains.

One of the subjects habitually drank 2 cups of tea and the other 10 cups of tea daily. A cup of tea contains about 2 to 3 grains tannin. Thus the subject taking 2 cups of tea was dosed with a total of about 150 grains of tea tannin in the 3 days, or about 48 grains a day, and the other with 210 grains in the same period, or about 70 grains a day. These quantities are based on the assumption that a cup of tea contains about 2.5 grains tea tannin.

At the end of the period under consideration, the first subject showed no effects in bowel action whilst the second developed a slight diarrhœa on the third day which ceased the next day, after the tannin administration ceased. In both cases the patients were reported by the medical officer as showing normal condition.

From these two experiments no conclusions can be drawn, of course, although the indications are that the action of tea tannin in the intestine is very different from that of *acidum tannicum*. Further experiments will be made, but the time and expense necessary for tea tannin extraction puts some limit on the extent of future work.

There are two obvious reasons why tea tannin should act differently in the intestines from *acidum tannicum*. The first is that tea tannin is a much weaker acid and the second that it has much weaker tanning powers than *acidum tannicum*.

In Great Britain the average daily consumption of tea tannin due to tea drinking is about 13 grains. This figure is based on an annual consumption of 9 lbs. tea *per capita*. Each pound of tea is assumed to give 200 cups, each cup containing 2.5 grains tea tannin.

India and China Black Teas

To return to another aspect of the discussion, it is now proposed to examine the claims made for China black teas in an oft-quoted paper published in the *Lancet* in 1911.(7) In all publications of this nature the advantage of getting in first is great. Although the statements made in this paper have been shown to be unjustifiable on more than one occasion, subsequent writers continue to quote the article and to base arguments on its assumptions.(20)

The worker in the *Lancet* saturated a tea infusion with ammonium sulphate and examined the precipitate obtained. In this he found caffeine and tannin usually in the ratio 1 to 3 and assumed that a compound of caffeine and tea tannin had been formed. Furthermore the assumption was made that such a compound had no harmful effect in the alimentary tract. The paper goes on to show that, as a rule, China teas have most of their tannin in the combined form whilst other black teas contain free tannin which is harmful.

If such a compound as caffeine-tannate existed in a tea infusion, it would be decomposed when the tea is drunk.

The ratio of caffeine to tannin precipitated from a tea infusion by ammonium sulphate varies according to the concentration of the solution, and ratios from 1 to 3 up to 1 to 12 with strong solutions have been obtained.

A previous reference (8) shows that Deuss prepared caffeine-tea-tannate in the absence of water, but observed that in water it is decomposed. This decomposition is an example of a normal case of hydrolysis of a compound of a weak acid and weak base.

Apart from the flavour, the main difference between India black teas (and this term is used to indicate black teas made according to European methods in India, Ceylon and Java) and

(7) *loc. cit.*

(20) G. H. Harden, A Treatise from the Medical Point of View on Various Facts relating to Tea, London, 1931.

(8) *loc. cit.*

China black teas is the amount of tannin in the liquors. The Chinese method of manufacture leads to a very full oxidation of the tea tannin and perhaps to the removal of much tannin as a condensed, insoluble phlobaphene compound. This, combined with leaf originally low in tannin content, produces a tea low in this respect. As a result, India teas have a thicker liquor than those of China, a quality sought after by confirmed tea drinkers.

Whilst it is not suggested that the thick liquor made by long infusions or by "stewing" tea is desirable, a certain thickness obtained by a short infusion is palatable. A 5-minute infusion extracts most of the desirable tannin bodies and about three-quarters of the caffeine. A second brew is proportionately poorer in these substances.

METEOROLOGICAL OBSERVATIONS IN NORTH EAST INDIA, 1931.

BY

C. R. HARLER

The tea crop 1927-31

The tea crop in North East India has shown considerable variation over the past five years, due partly to climatic conditions and partly to other causes. Crop restriction and changes in the fineness of the plucking in response to market conditions, make crop comparison useless as an indication of the season's weather. On certain plots at Borbhetta, however, plucking and other treatment has been constant during the past few years and such plots therefore reflect climatic conditions. These plots show the crop in 1931 to be about 10% ahead of that in 1930. In the Brahmaputra Valley the increase of 1931 over 1930 is about 4%.

Below is shown the percentage crop returns for the past 5 years, *viz.*, 1927 to 1931, in the Brahmaputra Valley and from certain Borbhetta plots. The 1927 crop is taken as 100% and subsequent crops are based on this figure.

	Brahmaputra Valley	Borbhetta
Season 1927	crop 100%	crop 100%
,, 1928	,, 109%	,, 103%
,, 1929	,, 112%	,, 110%
,, 1930	,, 101%	,, 102%
,, 1931	,, 105%	,, 112%

In the Jorhat district, in which Borbhetta is situated, the 1931 crop may be quoted as 104%. The difference between the Borbhetta value and that of Jorhat, *i.e.*, 8%, represents a decrease due mainly to finer plucking.

Both 1929 and 1931 were naturally bumper years. The 1928 season was a good one as shown by the Borbhetta crop but very good by the Brahmaputra Valley crop, which suggests free

plucking. The two years 1928 and 1929 precipitated the slump. A normal year in 1931, showing a crop of about 100% at Borbhetta and perhaps 95% in the Valley would have gone a long way to raising the market value of tea to an economic level.

The 1931 season in the Brahmaputra valley

The 1931 tea season in the Brahmaputra Valley was characterised by irregularity in cropping, following on alternate periods of favourable and adverse weather conditions. The year started with a drought, showing a total precipitation of only 2.26 inches to the end of March, against an average of 5.38 inches. Towards the end of March the temperature rose rapidly and the top soil at Tocklai dried out to about 10% moisture. But for the good carry over in soil moisture from the end of 1930, the soil would have been considerably drier and the tea would have suffered seriously.

April was wet, with a precipitation of 11.78 inches against an average of 8.03.

Following on the early drought the season started poorly with the result that the falling off in crop after the June flush was not very marked. When the season starts well, this June slump is very definite for a week or so, probably due to the fact that the secondary shoots have not yet reached the plucking level. When the season starts slowly, the primary shoots, *i.e.*, the ones coming straight from the pruned wood, are actually still being plucked well on into June.

At the end of June weather conditions improved and the middle and end of July and early August yielded good pluckings.

The early part of August was very wet, and the latter part dry and hot. At the end of this month the flush tailed off, partly following in the wake of the earlier flush and partly resulting from conditions which were first too wet and then too dry.

At the end of August the abnormally high temperatures ceased, rain fell in fair quantities and the new flush, following

a quiet fortnight, came in quantity at the beginning of September and continued for most of the month.

Early October witnessed a sharp fall in night temperatures and a corresponding fall in humidity. As a result an early close was anticipated. In the second week, however, temperatures and humidity rose, and conditions so improved that good crops were being collected at the end of the month. The back-end of the season was probably the best in Assam since the year 1919.

Rainfall and sunshine records

Rainfall and sunshine figures are recorded below. The average rainfall at Tocklai for the past 13 years, including 1931, is shown in the first column of the table. The 1931 monthly rainfall for Pabhojan, in Doom Dooma, and Sylee, in the Dooars, are also given.

In general, it may be said that the season in the Dooars closed early. In Doom Dooma as in the rest of the Brahmaputra Valley the end of the season was a very good one, although the bushes closed only a few days later than normally.

Table showing rainfall

	Tocklai		Pabhojan 1931	Sylee 1931
	Average 13 years	1931		
	ins.	ins.	ins.	ins.
January	1·04	0·64	0 84	0·14
February	1·35	0 92	3·56	0·21
March	2·99	0·70	3·78	0·53
April	8·32	11·78	14·89	3·41
May	8·41	6·66	8·51	11·66
June	13·70	15·64	22·19	26·92
July	15·21	13·54	22·63	46·34
August	13 32	13·33	13·85	23·12
September	10·69	9·79	14·43	41·27
October	5·03	4·56	5·86	4·91
November	1·16	0·79	1·41	0·23
December	0·42	0·75	0·54	*nil*
Total ...	81·63	79·10	112·35	166·74

Sunshine records are tabulated below. These include the monthly average, in hours, recorded at Tocklai during the past 14 years, including 1931. The 1931 records are given for Tocklai, Pabhojan and Sylee.

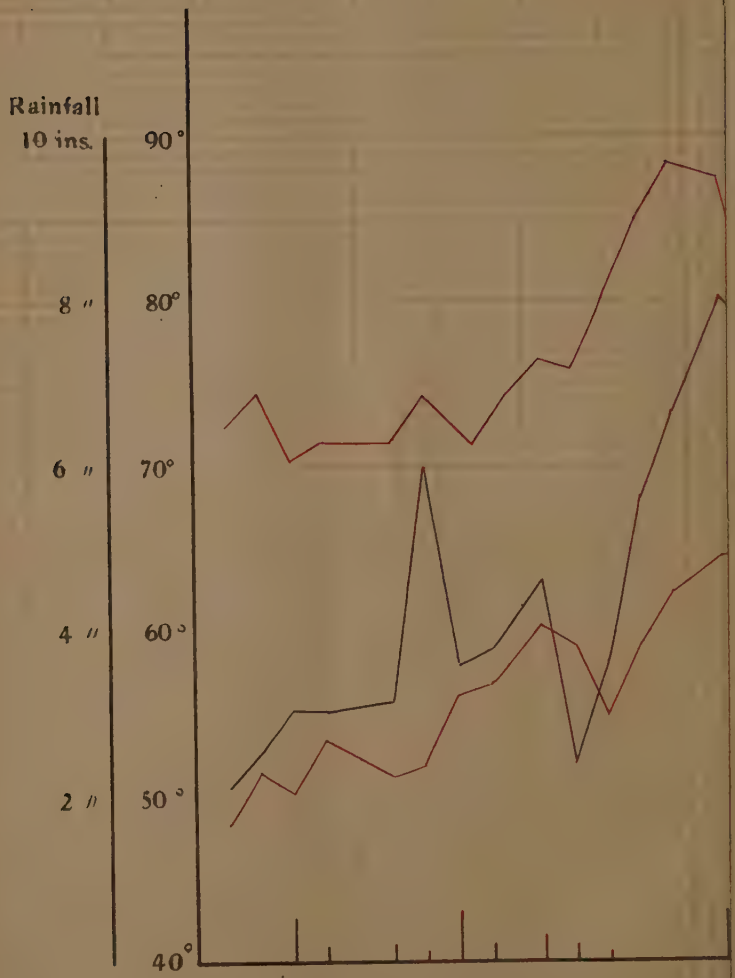
Table showing sunshine in hours

	Tocklai		Pabhojan 1931	Sylee 1931
	Average 14 years	1931		
	hrs.	hrs.	hrs.	hrs.
January	165	140	145	180
February	167	142	100	181
March	191	221	194	222
April	158	152	127	199
May	152	163	148	158
June	127	96	100	137
July	134	138	117	69
August	145	161	166	153
September	126	94	87	101
October	160	175	192	270
November	167	156	188	258
December	163	144	178	221

The records at Pabhojan are available only from 1927, *i.e.*, for 5 years, and averages on such a short period do not signify much. At Sylee records for 7 years are available for the critical months, *viz.* April to October. Owing to the opinion that sunshine is an important factor in mosquito blight (*Helopeltis theivora*) control, all the available figures are put on record below. No comment is made at this juncture.

Sunshine at Sylee in hours

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1925	...	...	...	118	101	124	94	96	86	...	...	...
1926	...	...	...	180	147	1	66	127	170	...	...	...
1927	...	...	190	217	216	144	114	149	144	228	196	142
1928 ... 190	232	255	109	169	91	111	123	133	171	...	...	
1929 ... 196	221	275	192	196	112	104	144	207	187	111	170	
1930 ... 155	204	177	185	219	136	161	91	197	164	225	241	
1931 ... 180	181	222	199	158	137	69	153	101	270	258	221	



Observations made at Tocklai Experimental S

The weather chart for 1931

The weather chart for 1931, shown opposite, is drawn on the lines adopted over the past 12 years.

The top curve shows the soil moisture, which can be correlated with rainfall. The second curve shows the average daily wind. In the spring, when the atmospheric depression over Tibet becomes appreciable, the wind increases, reaching a maximum in April. During this period high winds are liable to occur, although nothing of a cyclonic nature has been recorded since 1924. After the Monsoon has been definitely established, the wind shows a general decrease till the end of year, and even the change in direction from southwest to northeast with the change in the Monsoon, is not marked by any definite break in the wind curve.

The irregularity in temperature and rainfall during the season has already been commented on.

The crop curve represents the green leaf from the Tocklai Clearance, an area of about 2½ acres. Half the area is pruned annually and half biennially. In the year under consideration, 1931, both areas were pruned. It will be noticed that both curves follow the same general line. The irregularities in the curve peculiar to the season have already been discussed.

MANURING

Part II

(Continued from Journal pt. IV, 1931)

BY

H. R. Cooper

In good times, that is when tea sells freely at remunerative prices, manure is applied to increase crop and therefore profit. When the market is glutted, the only reason for manuring in the case of most estates is to reduce the cost of production without lowering the quality of the product.

Manuring and quality.

Since considerable doubt is still felt regarding the connection between manuring and quality it will be useful to recapitulate the evidence on this point. Three different considerations arise :—

(*a*) The effect on quality of increased yield from manuring in general.

(*b*) The effect on quality of expensive organic forms of nitrogen compared to that of cheap soluble artificials.

(*c*) The effect of potash and phosphoric acid on quality.

(*a*) Slow growth, from low temperatures or from "green fly" attack, certainly improves quality. It is often argued that therefore manuring by increasing rate of growth must lower quality. The argument is, of course, fallacious. Slow growth from over-high temperatures, from thrips attack, or from such diseases as red-rust has never been observed to increase quality, but certainly appears to lower it.

Judging from the prices obtained for teas of gardens of very low yield compared to prices obtained by neighbouring well-manured, better yielding gardens there is also no evidence which would connect quality with starvation.

Increased yield from manuring, also, comes not so much from increased rate of growth, as from bushes of increased spread carrying a larger number of strong shoots, and flushing as well from outside branches as from centres, if plucking is close. The more even size of the shoots from such healthy bushes makes for improved quality.

Separate manufacture of leaf from tea at Borbhetta giving 13 mds. per acre receiving 150 lbs., sulphate of ammonia annually, gives teas valued as highly as those from the corresponding unmanured plots giving 9 mds. per acre. On the other hand it is true that the plots (in the same block), which receive per acre 600 lbs., sulphate of ammonia annually and yield about 20 mds. tea per acre, do produce teas of definitely lower quality than those from the unmanured plots, though even then there is not very much in it. In practice, areas of very high yield such as very rich "peat" bheel soils do give teas not of the highest class: so that very high yields may be associated with reduced quality if other things are equal; though it is believed that with really strict plucking at close intervals such rich areas would give better teas than areas of low yield coarsely plucked.

It is difficult to fix a point at which quality may be expected to deteriorate. There are a number of gardens among those producing the best quality in Assam which average over 12 mds. per acre, and indeed most of the plains gardens producing teas above the average in quality, also produce yields above the average. All these gardens produce with the aid of manures.

A mature tea bush can hardly be considered to be in good healthy condition unless it produces at the rate of about 10 mds. per acre when top-pruned and fully plucked. This yield is above the average only because most gardens have in bearing a number of poor sections, and poor patches, and numbers of vacancies and non-yielding bushes among good sections. A general increase in yield per acre is not desirable on the present market unless the gain is balanced by the abandonment of poor unremunerative areas: but it appears that there is room for a general increase

in yield per acre from the area kept in bearing without fear of reduction in quality.

There is no evidence from any source to indicate that moderate manuring has any influence on quality.

Where prices have improved after adoption of reasonable manuring programmes, increased fineness of plucking also has been practised. It is true that most of the gardens in the plains making teas of notable quality also produce high yields. Good tea yields well even with fine plucking, and provides no temptation to make a crop cheaply by taking coarse leaf at long intervals. Good profits also have allowed the provision of well equipped factories. It is not claimed that manuring directly improves quality, but it is believed that in moderation it makes no difference in one way or the other.

Crops beyond the capacity of the labour force to take, when just ready, or beyond the capacity of the factory to manufacture properly, certainly do cause reduced quality. Manuring is frequently blamed for effects due to one or both of these causes. Manuring should aim at providing, as cheaply as possible, a crop within the capacity of plucking force and factory.

(*b*) All nitrogenous compounds are converted into ammonia and then to nitrate in the soil, before being taken by the plant. There is no question, therefore, of any difference in the *quality* of the nitrogen which the bush obtains. Any difference there may be, lies in the *rate* at which the nitrogen becomes available. The full effect of the slower acting organics is slower to appear and is spread over a longer period.

Large doses of quick-acting artificials may give too big a second flush, and somewhat spoil its quality. Where this is feared the artificial should be applied in divided doses.

20 lbs. nitrogen in March and 20 lbs. in June, both as sulphate of ammonia give almost exactly the same yield per month as do 40 lbs. nitrogen as blood meal applied in March.

To get delayed effect, therefore, there is no need to have recourse to expensive organic manures.

(*c*) The evidence on the effect of potash and phosphoric acid on quality is not yet quite so clear. No actual trials of separate manufacture of tea manured with and without them are on record. Analysis of leaf from plots at Borbhetta receiving per acre (1) 40 lbs. nitrogen, (2) 40 lbs. nitrogen and 60 lbs. potash, (3) 40 lbs. nitrogen and 60 lbs. phosphoric acid, (4) 40 lbs. nitrogen, 60 lbs. potash and 60 lbs. phosphoric acid, showed exactly the same leaf composition in all four cases, in contents of nitrogen, potash, phosphoric acid, tannin, soluble oxidizable non-tans, total soluble solids, ash, and moisture. It is unlikely therefore that the use of potash or phosphoric acid could make any difference to quality. That the same crop containing the same percentages of potash and phosphoric acid was made whether potash or phosphoric acid were applied or not would appear to indicate that the additional potash and phosphoric acid had not been taken by the bushes, which obtained their full requirements of these substances from the unmanured soil. If the additional potash and phosphoric acid applied as manure did not enter the bushes it would appear impossible that they could affect the quality of the leaf grown.

When very large doses of nitrogen are used, the soil may not be able to supply sufficient potash or phosphoric acid to balance the nitrogen. For example, at Borbhetta, 120 lbs. nitrogen, 120 lbs. potash and 120 lbs. phosphoric acid give much larger crops than 120 lbs. nitrogen, 30 lbs. potash and 30 lbs. phosphoric acid; but in this case the teas from the plots receiving the smaller doses of potash and phosphoric acid were considered even slightly preferable; so that, in this case at any rate, the shortage of potash and phosphoric acid showed up in reduced crop and not in reduced quality.

We can find no evidence therefore which would justify any large expenditure on potash and phosphoric acid as manure in the hope of improving quality.

From the above evidence it seems clear that manuring with nitrogen, even in the cheap quick-acting soluble forms is likely to have no effect on quality so long as over-large doses are not applied at any one time, and that crop is not increased beyond the capacity of the labour force to pluck when just ready, or beyond the capacity of the factory to manufacture properly.

Doses of nitrogen required for maintenance of a particular crop

In the cases of all crops, if land is cropped continuously without manuring, the yield per acre falls until a roughly constant small yield is maintained.

At this point the total losses of nitrogen from the land, that is the nitrogen removed in crop plus the nitrogen washed out from the soil, are balanced by gains of nitrogen from the atmosphere through the agency of nitrogen-fixing micro-organisms present in the soil.

Any given annual dose of nitrogen as manure will maintain some higher crop dependent on the quantity of nitrogen supplied. In all cases, of course, sufficient of other necessary plant foods such as potash and phosphoric acid must be obtainable from the soil or supplied as additional manure.

At Rothamsted, for example, the following were the average yields of wheat for the 74 years 1852-1925, the unmanured plots having received no manure since 1839.

	lbs. nitrogen per acre	Wheat cwt. grain per acre. average yield	Increase per annum cwt.
No manure	0	6·7	.....
200 lbs. sulphate of ammonia ...	43	12·5	5·8
400 „ „ „ ...	86	17·6	10·9
600 „ „ „ ...	129	20·1	13·4
14 tons farmyard manure	200	19·4	12·7

Experiments at Borbhetta have not continued sufficiently long to enable us to give with accuracy similar figures for tea. But it is quite clear that the same principles will apply, except that it appears that the increase of crop from manuring of tea up to 120 lbs. nitrogen per acre at least, is proportional to the quantity of nitrogen applied,* and that the increase per unit of nitrogen does not fall off with increasing doses as it does in the case of wheat and most other crops not grown for leaf.

It will be understood that in the following pages the estimates given, of nitrogen requirements for particular purposes, rest on no sure foundation of long-continued actual measurement; but it is thought necessary to give rough indications of the effects which appear on the present evidence, likely to be obtained, in order to provide a basis on which manuring programmes may be drawn up with some hope of fulfilling requirements, and to illustrate the manner in which manuring is likely to cheapen production.

Judging from such results as we have, and from observations in practice, the following may be taken as roughly the expectations of average crop which would be maintained under continuous similar treatment on normal soils in North East India.

Total nitrogen as manure in lbs. per acre.	Average annual crop in mds. tea per acre.
0	5 to 6
20	7 to 8
40	9 to 10
60	11 to 12
80	13 to 14

The above figures can, of course, be taken only as rough approximations and assume that the soil is normally favourable for tea, that the tea is normally healthy *i.e.*, no serious disease of the stem or root is causing an abnormal percentage of vacancies

* See Tables on p. 47.

and non-yielding bushes, and that crops are not seriously reduced by persistent attacks of such pests as mosquito blight. Crops in abnormally bad seasons in districts liable to extremes, and crops after heavy pruning in all districts, must be excluded when calculating such averages.

These averages assume, also, that cultivation, pruning and plucking are efficient.

It must be understood that these averages quoted are to be expected as roughly constant yields after a number of years of continuous similar treatment.

Tea giving say 5 mds. per acre will not be raised to 13 mds. per acre after the first application of 80 lbs. nitrogen per acre but would be expected to reach that yield after a number of years of continuous application of 80 lbs. nitrogen per acre, and to maintain about that yield (subject to seasonal fluctuations) so long as the same food-supply is maintained. Similarly a good soil still near its virgin condition and containing naturally a good supply of available nitrogen may give 14 mds. tea per acre after only 30 lbs. nitrogen per acre, but would be expected to fall gradually to about 9 mds. per acre, if only 30 lbs. nitrogen continue to be applied.

The rate of fall in such cases as the latter would be expected to be slow so long as the tea is merely top-pruned, because good tea occupies a soil so nearly completely that losses of nitrogen from washing out would be very small, and the prunings added to the soil annually provide in quantity the cellulose which is necessary for the work of the nitrogen-fixing bacteria, and maintain the physical condition of the soil.

Whenever such tea is heavy pruned so that the cover is removed and more working of the soil by cultivation becomes necessary, while a greater call is made on the nitrogen of the soil in order to grow new frames, then the rate of deterioration would be expected to be more rapid and it certainly appears in practice that it is so.

Cost of production of extra crop from manuring

Assuming that if no manure at all be applied, only 6 mds. tea per acre at most may be expected to be maintained, while annual additions of 40 lbs. nitrogen per acre will maintain 10 mds. tea per acre; then an extra 4 mds. tea per acre is to be expected annually from the use of 40 lbs. nitrogen per acre.

Forty pounds nitrogen may be provided in the form of 195 lbs. sulphate of ammonia (now quoted Rs. 122/- per ton), for an expenditure, in Calcutta, of Rs. 10/10. In the cases of most gardens the total cost of the application including freight, carting and application would be about Rs. 14/- *i.e.*, the cost of manuring to produce an extra maund of tea is about Rs. 3/8-. This extra crop from manuring still has to be plucked, manufactured, put in boxes, carried to market, and certain other marketing charges have to be met.

Before probable profits from manuring can be estimated these harvesting and marketing costs must be estimated. They will be different for different gardens and particularly for different districts. As an illustration, a rough average for Assam may be :—

Cost per maund of tea of increased crop from manuring.

	Rs.	As.	P.
Manuring	3	8	0
Plucking	5	0	0
Extra labour in factory ...	2	0	0
,, fuel	2	0	0
Boxes	3	0	0
Carting and freight to Calcutta	1	8	0
Brokerage, Insurance, and other costs such as agency charges.	2	0	0
TOTAL Rs. ...	19	0	0

The cost of the increased crop for a garden for which these estimates happen to be correct would therefore be Rs. 19/- per maund of tea or about 3.8 annas per lb.

It is improbable that, even with the strictest economy, a garden in Assam producing only 6 mds. per acre could put it on the Calcutta market for less than As. 8/- a pound or Rs. 40/- per maund. On the above figures it could produce an extra 4 mds. of tea for Rs. 19/- per maund. In this case, the total cost of production for the manured garden would be :—

6 mds.	@ Rs.	40 0 0	= Rs.	240 0 0
4 ,,	@ ,,	19 0 0	= ,,	76 0 0
10 mds.			TOTAL Rs.	316 0 0

average Rs. 31.6 per maund or about 6 annas 5 pies, per lb.

In such a case moderate manuring would reduce cost of production from As. 8/- per lb. to As. 6/5 per lb.

This assumes, of course, that the existing factory can deal with the extra crop and that labour can be found for the plucking without increasing recruiting costs.

In this manner, it must pay many gardens to increase their present crop by manuring; but it is perhaps more to the point to insist that gardens now producing good yields within the capacity of existing labour force and factory, must not allow yields to fall off for lack of a little cheap manure.

The table on p. 41, provides a sufficiently good indication for present purposes of the annual total nitrogen supply which should be provided to maintain a given crop, without fear of deterioration from shortage of food. This total annual supply includes the nitrogen obtained from all sources except that produced by the nitrogen-fixing organisms living free in the soil. It includes for example nitrogen provided by shade trees.

Shade trees

The quantity of nitrogen per acre provided by shade trees, of course, depends upon many factors but very largely upon the distance apart, size, and health of the trees. At least one case is known where yields above 14 mds. per acre were maintained for many years under shade trees and without any other sort of manure. Such cases are very rare and when they do occur it may be assumed that the shade provided is far too thick to allow the production of reasonably good tea. Under thick shade, wiry shoots with very long lengths of stalk between the leaves, are grown; and such shoots, even when plucked strictly, make washy teas, and are liable to show fibre if not stalk in the dry leaf.

Reasonably efficient shade trees appear to provide effect about equal to that of 30 lbs. nitrogen per acre without reducing the quality of the leaf. In fact, in experiments at Pabhoi, teas grown under moderate shade at the time of the second flush were preferred to those made from similar but absolutely unshaded areas, the latter being reported on as "thin". Well-grown, healthy Sau trees at about 50 feet apart appear to give such efficient shade.

In estimating nitrogen requirements therefore the nitrogen to be added as manure to a properly shaded area may be taken to be about 30 lbs. less than the quantities estimated in the table on p. 41.

Thirty pounds nitrogen as sulphate of ammonia would cost roughly Rs. 10/- per acre applied. Assuming that shade trees have an average efficient life of about 15 years, the total value of shade trees to a garden may be estimated at about Rs. 150/- per acre. To plant about 18 shade trees per acre and to get rid of them when canker and old age have reduced their value to negligible proportions is hardly likely to cost a total of Rs. 150/-.

This estimated value of shade trees, depends upon the cost of artificial manures which is likely to increase rather than to decrease in future. Shade trees also have value on account of the direct effect of light shade on tea; and, also, the cover they provide is of assistance in keeping down jungle so that their presence

reduces cultivation costs. Hence the estimate of Rs. 150/- per acre as the value of shade trees to a garden must be looked upon as an absolute minimum and it is advised that shade trees should be established on normal soils though there are cases where their presence probably is undesirable; for example, at high elevations in the hills where all the sunshine obtainable is desirable; or low-lying flats in the Surma Valley where roots are confined to the surface by a high water-table and consequently the drying out of the soil in dry seasons is increased by the presence of trees which even if leafless transpire through their bark. Some observers have considered them similarly undesirable on certain exposed southern or western slopes in districts liable to severe spring drought; but as there is here strong probability of deep root range, it seems probable that in such cases shade trees will prove generally desirable if not planted over-thickly.

Where reasonably spaced shade trees in good condition are established, yields of 8 to 9 mds. per acre are maintainable without other manure so long as work is good in other direction, *e.g.*, vacancies must be replaced as they occur. Normally, among such sections there will be patches of poor tea due to white-ant teelas, places where heaps of heavy timber were burnt after clearing, places where subsoils were exposed when levelling before planting, or places where shade trees grow poorly or not at all: such patches should receive individual treatment in order to maintain the average. Apart from the waste of expenditure on such unremunerative areas, even growth over the whole area plucked is very desirable from the point of view of quality.

Where yields exceeding 8 to 9 mds. are required to be maintained on shaded areas about 10 lbs. nitrogen per acre, generally as cheap soluble artificial, should be applied annually, for each extra maund of tea produced.

Where moderate yields up to about 10 mds. per acre are required, it is believed, on the evidence at present available, that no potash or phosphoric acid need be applied as manure, at least for some years; though it is not yet known how long normal soils will carry on without such addition.

The use of larger dressing of nitrogen

When the total application of nitrogen including that supplied by shade trees exceeds about 40 lbs. nitrogen per acre it will be on the safe side to supply some potash and phosphoric acid also. The potash and phosphoric acid required for maximum efficiency must vary for every different soil and probably also with different climates, but only experiments on different soils in different climates can discover actual requirements for each set of circumstances.

On the evidence at present available it is suggested that dressings supplying nitrogen up to 40 lbs. per acre may be applied without phosphoric acid or potash; but dressings exceeding 40 lbs. nitrogen per acre should be accompanied by half as much each of potash and phosphoric acid as of nitrogen. That is dressings of 60 lbs. nitrogen should be accompanied by 30 lbs. potash and 30 lbs. phosphoric acid, and dressings of 120 lbs. nitrogen by 60 lbs. potash and 60 lbs. phosphoric acid.

When in the following paragraphs dressings of nitrogen exceeding 40 lbs. per acre are referred to, they should be accompanied by such quantities of potash and phosphoric acid.

Effects in first year of application

(1) The crop increase obtained during the earlier years of application at least, is roughly proportional to the quantity of nitrogen applied. For example the following results have been obtained at Borbhetta.

Manure per acre annually	lbs. nitrogen per acre annually	Mds. tea per acre	Gain	
		Total 1930 and 1931	Mds. tea per acre in 2 years	per cent.
(*a*) *nil*	0	17·55	.....	.....
195 lbs. sulphate of ammonia ...	40	22·16	4·61	26
395 „ „ „ ...	80	27·02	9·47	54
385 „ „ „ ...	120	31·45	13·40	79
		1931	*in 1 year*	
(*b*) *nil*	0	10·15	.....	.....
5 tons cattle manure ...	40	10·66	0·51	5
10 „ „ „	80	11·24	1·09	10
20 „ „ „	160	12·48	2·33	22

(2) Increased crop from manuring in the first year is roughly proportional to the yield which the tea would have given if unmanured.

For example 195 lbs. sulphate of ammonia were applied experimentally on three different blocks of tea at Borbhetta in 1931. In all three cases the tea had not previously been manured.

	Yields in Mds. tea per acre		Gain	
	Unmanured	Manured	Mds. tea per acre	per cent
(*a*)	5·56	6·94	1·38	24·8
(*b*)	8·93	11·22	2·29	25·6
(*c*)	10·85	13·48	2·63	24·3

If these two principles are applied, we are enabled to estimate what will be the effect of a given dose of manure in the first year of application, assuming that a manure is used which is as efficient as sulphate of ammonia. Some forms of nitrogen, (*e.g.*, cattle manure, results from which are quoted above) have much lower efficiency.

In all these experiments sulphate of ammonia has given about 25% increase for each 40 lbs. nitrogen used. This efficiency is probably greater than the average. The tea experimented on was young and healthy and in very good condition to make full use of increased food supply. It was plucked very strictly and completely down to the *janam* every week so that all the leaf grown was taken. Under practical condition plucking is rarely so efficient, and most sections of commercial tea contain a number of diseased or worn-out bushes which do not respond equally to additional food.. Response also is not equally good in all seasons : factors other than food supply frequently affect crop very greatly.

Probably not more than 20% increase over what would have been produced unmanured can be looked for, for each 200 lbs. sulphate of ammonia used : while some bushes, which are "bad

doers" from the presence of disease or perhaps from old age, may react still less favourably. Soils in "bad condition" also would give poorer results.

It will be understood that where the digestive system of a bush is seriously imparied, *e.g.*, from presence of serious root disease, or where leaf (in which the crude raw material is manufactured into plant food) is seriously reduced in efficiency, as by bad mosquito blight attack, then little immediate benefit is to be expected from an increased food supply.

To estimate the crop likely to be obtained after manuring, it is first necessary to estimate the crop likely to be produced without manure. Seasonal factors alone may easily cause a variation of ten per cent. in crop for one season compared to the next, but assuming that plucking, pruning and cultivation are the same in both seasons, the crop for the current season usually may be taken as that likely to be made in the following season if no manure is applied in either season.

The increase in crop per acre likely to be obtained in the first season of manuring then may be roughly estimated from the following formula :—

$$\frac{\text{estimated crop unmanured} \times \text{lbs. nitrogen in efficient form per acre}}{5 \times 40}$$

or :—

$$\text{lbs. nitrogen in efficient form required} = \frac{\text{increase in crop required} \times 200}{\text{estimated crop unmanured.}}$$

Using this formula it will be seen that it pays best to manure reasonably good tea, in fact, for the first year at least, it may not pay at all to manure poor tea. For example, 200 lbs. sulphate of ammonia would be expected to raise to 6 mds. per acre tea which would have given 5 mds. if unmanured, assuming that the 5 mds. comes from an area perhaps very vacant but in which such bushes as exist are reasonably healthy though small. The manure would cost about Rs. 14/-, and if harvesting and marketing costs amount to Rs. 15/- per maund then the extra maund of tea costs Rs. 29/- or nearly 6 annas a pound; and, on the pre-

sent market, tea in some districts would not fetch this price, and so the manuring would show a loss.

Even if the manuring did show a profit because the tea sold well, it is very likely that a section yielding only 6 mds. per acre would still show a loss on the whole. In that case such an area either should be abandoned altogether and the crop so lost made up by moderate manuring of remaining better areas, or the poor area should be manured to bring it rapidly into profitable bearing. If the low yield is due only to the presence of vacancies then, of course, either replanting or infilling on a very large scale would be a necessary preliminary, and few gardens might be able to face such expenditure just now. If however, the low yield comes from a nearly full section of small, starved, but reasonably healthy bushes, then manuring alone will do what is required, but heavy doses would be required to bring such an area rapidly into a profitable bearing. For example a dose of 120 lbs. nitrogen per acre would be expected to produce a 60% increase, *i.e.*, it should give a crop of 8 mds. from an area which if unmanured would have given only 5 mds. that year. After this heavy dressing in the first year it is probable that only 30 lbs. nitrogen applied annually would maintain the crop of about 8 mds. per acre.

It is improbable that, at the present time, such heavy dressings often will be contemplated for complete sections, but such heavy dressings are advised for the purpose of bringing bad patches within good sections up to average, where the "bad patch" is not clearly due to some cause other than food supply, *e.g.*, an old white-ant teela, an old house site, or inefficient drainage. Bad patches are very often due to no more than the exposure of infertile subsoil after levelling before planting, and in such cases manuring will bring them up to average.

Abandonment of poor areas without loss of crop

Another way in which manuring may be used to reduce cost of production is by allowing the complete abandonment of poor areas without loss of crop.

Every planter with areas of poor tea on his hands, knows how very greatly they increase his expenditure on cultivation, and particularly on plucking. The presence of the thick jungle which so often has to be tackled and the poor return for a day's work in plucking them, causes such poor labour attendances for work on days allotted to such areas that very poor use is made of the labour which is so expensively recruited, and maintained, apart from wages.

It is suggested that in the cases of many gardens it will pay to abandon poor areas particularly of old Hybrid or China tea (which use so much labour for plucking compared to indigenous tea) and to make up the balance of the crop required to employ labour and factory fully, by manuring of the better areas.

A garden of 1,000 acres is generally made up of sections of very different yield, for example an average of 8 mds. per acre might be made up in the following manner :—

		Total crop mds.
400 acres averaging	10 mds. per acre ...	4,000
400 ,, ,,	8 ,, ,, ,, ...	3,200
200 ,, ,,	4 ,, ,, ,, ...	800
1,000		8,000

The area giving 10 mds. per acre might well be left under its present treatment. It is not suggested that its yield could not be increased with profit, but it is already yielding well enough to produce tea reasonably cheaply.

The area giving 4 mds. per acre in the plains is probably running at a loss. If it is to be abandoned without loss of crop, the area now giving 8 mds. per acre must be improved to give 10 mds. per acre. On the assumptions made, to effect this increase would require about an extra 50 lbs. nitrogen or 250 lbs. sulphate of ammonia in addition to whatever had been used in maintaining the previous yield of 8 mds.

Probably this quantity of nitrogen could be applied to an area previously unmanured except for shade trees without additional potash and phosphoric acid. In that case the extra manure would cost in Calcutta about Rs. 13/9 or about Rs. 16/8 applied.

To be on the safe side it would be preferred to apply a balanced mixture providing about half as much each of potash and phosphoric acid as of nitrogen.

The cheapest efficient such mixture at present prices is :—

Nicifos	...	46 per cent.
Nitrate of potash	...	25 ,, ,,
Sulphate of ammonia.	...	29 ,, ,,

This supplies about :—

16.6% nitrogen
8.2% potash
8.3% phosphoric acid.

And the mixture at present prices would cost about Rs. 154/- per ton in Calcutta.

50 lbs. nitrogen would be supplied by about 300 lbs. of the mixture, which would cost Rs. 20/10 in Calcutta, or perhaps about Rs. 25/- including freight and application.

The Rs. 25/- spent on manuring might not in all cases raise crop from 8 mds. to quite 10 mds. though in many cases it would do more : but even if it were found necessary to increase this sum, it would probably prove less than the actual cost of maintaining half an acre of tea giving 4 mds. without manure; particularly when the indirect losses due to a dissatisfied labour force are taken into account.

The comparatively heavy dose would be expected to be required only for one year, after which only a total from all sources of about 40 to 50 lbs. nitrogen per acre should be necessary to maintain the crop : *i.e.*, about 20 lbs. nitrogen more than had been used to maintain the crop of 8 mds. : so that when the state

of roughly steady yield has been attained, it should prove much cheaper to maintain a reduced area of good yield than to keep in bearing areas of very poor tea.

Young tea and Infillings

For a number of years after planting, young tea absorbs expenditure without giving any return, and the expenditure exceeds income for a further term until the tea reaches a reasonable yield per acre.

This unprofitable term of years may be reduced very greatly by manuring; more particularly, of course, in the case of tea replanted on soil exhausted by many years of cropping, but even on a normally good soil manuring offers a considerable real economy in saving time.

One ounce sulphate of ammonia per plant is sufficient for a good dressing for plants up to about three years from seed. A circle of 3 ft. diameter about the collar would cover the normal spread of the roots of the young plant. Manure should be scattered as evenly as possible over each such circle and forked in.

Assuming planting to be $4\frac{1}{2}' \times 4\frac{1}{2}'$ triangular such circles occupy rather less than half the total planted area so that the concentration of manure about the roots is double the rate of application per acre.

For $4\frac{1}{2}' \times 4\frac{1}{2}'$ triangular planting, one ounce per plant requires only about 155 lbs. sulphate of ammonia per acre costing, at Rs. 122/- per ton, Rs. 8/7 in Calcutta.

As plants grow the circle of application should be increased so that its circumference lies a few inches outside the spread of the branches, until, when the bushes nearly touch, the manure is broadcast.

The rate of application may be increased with advantage for older plants, 2 ozs. per plant, or about 4 mds. per acre, may be considered a very good dressing, but for such large dressing the

use of the balanced mixture given on p. 47 at 2½ ozs. per plant would be preferable.

Similar treatment for all infillings is very strongly advised. Without some such treatment, infillings commonly do nothing for years, and often remain practically useless. The usual basket of cattle manure is very useful in improving the physical condition of the soil, but its effect on growth is too slow. When used it should not be placed at the bottom of the hole as is sometimes done, but mixed with the last 9 inches of top soil when that is replaced. In addition, 2 ozs. sulphate of ammonia is recommended, either mixed with the cattle manure, or applied separately and forked in afterwards. No potash or phosphoric acid is necessary in such a case as the cattle manure provides plenty of both for years to come. Infillings so treated make splendid growth so that they can be considered to be really established after one year in the soil. If no cattle manure is available, 2½ ozs. of the complete mixture should be used. The treatment can be repeated annually till the infilling is considered to be sufficiently well grown to require no more than the treatment given to the rest of the section.